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Effect of Mixing Fiber Cocktail on Flexural Strength of Concrete

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Abstract

The objective of this study was to examine the effect of mixing fiber cocktail on cracking strength of concrete. The research work has been carried out to evaluate the effect of "cocktail fibers" on reinforced concrete. Cocktail fiber is a mixture of steel fibers (SF) and polypropylene fibers (PPF). Comparison was carried out by preparing and testing 30 specimens of plain & reinforced concrete incorporating different ratios of fibers. Monofilament polypropylene fibers and undulated steel fibers were used in various dosages and their effect on the cracking strength in terms of compressive strength as well as ultimate load capacity was observed. For this purpose cubes (150 x 150 x 150 mm) and beams (150 x 225 x 1975 mm) were cast for compressive strength test on cubes and two point loading test on beams. The cubes and beams were cast in groups, such as, group A (concrete without any fiber), group B (steel fibers @ 60 kg/m³), group C (PP fibers @ 0.7 kg/m³), group D (PP fibers @ 1.5 kg/m³), group E (cocktail fibers @ 60 kg/m³ of steel fibers + 0.7 kg/m³ of PP fibers) and group F (cocktail fibers @ 60 kg/m³ of steel fibers + 1.5 kg/m³ of PP fibers). From test results, it was concluded that the addition of polypropylene, steel and cocktail fibers enhanced the initial cracking and post cracking behaviour of reinforced concrete. However, with the addition of steel fibers the compressive strength of concrete reduced which is a trade-off between the initial cracking strength and compressive strength.

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Keywords: cocktail; fiber; monofilament; polypropylene; flexural; compressive.

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1. Introduction

The strength, durability and other characteristics of concrete depends upon the properties of its ingredients, the proportion of mix, the method of transporting, compacting, placing and curing. Good concrete has to satisfy performance requirement in plastic and hardened state. In plastic state, concrete should be workable and free from segregation and bleeding. In hardened state, concrete should be free of cracks, strong, durable and impermeable. Unfortunately, concrete's low tensile strength and brittle characteristics make it prone to cracking. The inclusion of fibers provides an energy absorbing capacity that can maintain the structural integrity of concrete during fracture al-tayyib, a.h.j. and al-zahrani, m. M. (1990). Cracks allow the penetration of water or solution into concrete, which may cause corrosion of the reinforcement. Corrosion causes expansion within the concrete which results in destructive forces causing cracking and disintegration. Cracks occur in concrete even before environmental distress occurs. Fibers are expected to improve the properties of concrete both in the unhardened and hardened state. In the unhardened state, fibers increase resistance to plastic shrinkage cracks. In the hardened state, fibers improve the strength (Impact, tensile, flexural and toughness) of concrete, depending on fibers types, shape, size and amount (Mindess 1993).

The purpose of this study was to evaluate the effect of different fiber types and volumes. Commonly used steel and polypropylene fibers were used in different amounts. In this report, the effect of fibers has particularly been studied on the cracking strength of concrete in terms of studying the effect on the crack strength, ultimate load capacity, deflection and compressive strength. Shrinkages and loads that are applied, lead to crack formation on the surface. These cracks are harmful as they pose threat to the service ability and strength of structure (Beaudoin 1990). It is a known fact that the cracks can never be eliminated completely however they can be minimized and the age of structure can be increased (Taylor et al. 1997). The main point that is covered in this study is the use of fiber cocktails. The polypropylene fiber is known to have helped in reducing the plastic settlement and plastic shrinkage cracks plus the fire damage and the freeze/thaw damage. On the other hand, steel fiber has successfully been used to increase resistance to cracks due to drying shrinkage and tensile loadings (Raghunath and Suguna 2008). The working idea behind this study is to use a mix. of polypropylene and steel fibers called "cocktail fiber" thus obtain a fiber combo which will help to reduce cracking due to plastic shrinkage, plastic settlement, and the fire and freeze/thaw action.

2. Experimental Program

The fibers namely polypropylene, steel and their cocktail mix are used to carry out this study and the comparative study approach has been used to analyze the obtained results. Monofilament polypropylene fiber and undulated steel fiber are used in various dosages and their effect on the cracking strength in terms of compressive strength, ultimate load capacity and deflection has been observed. Cubes and beams were cast and using the compressive strength test for cubes (150x150x150 mm) and two point loading test for beams (150x225x1975 mm), the first crack strength and ultimate failure strength are examined. The cubes and beams cast with polypropylene fiber (0.72 kgm^{-3} & 1.5kgm^{-3}), steel fiber (60 kgm^{-3} & 120 kgm^{-3}) and cocktail fiber (0.72 & 60, 0.72 & 120 kgm^{-3}) are tested and the results are compared with plain concrete samples declared as controlled cubes and beams.

2.1. Materials Used

Materials, their proportions and specimens used for the current study are as follows:

Materials:

a. Cement: ASTM type I, Ordinary Portland Cement (Bestway Brand) was used.

b. Aggregate: Coarse aggregate ¾" (from Sakhisarwer) and fine aggregate (Pit Sand) were used.

c. Fiber:

- Steel Fiber: Continuous deformed steel fibers Novocon XR1050 low carbon cold drawn steel.

  Tensile Strength = 827 MPa,

  Length= 50 mm

- Polypropylene Fiber: Monofilament Fiber, Crack Elongation 20%±5%,

  Fiber Dia: 0.02-0.05±0.005,

  Melting Point: 160^o-170^o

  Tensile Strength $\geq$450 MPa

  Size = 6, 10,12,15,19,20,24,48 mm

  Resistance to acid and alkali = Strong

Proportions of concrete specimens and reinforcements:

a. Concrete mix Ratio: (1:2:4) to achieve 21 MPa

b. W/C= 0.45

c. Reinforcement**:** Main Bar: # 3; Twisted Bar ASTM G – 60.

d. Shear Reinforcement: # 2 Round; ASTM G – 40.

e. Steel Fibers Ratio: 60 kg/m^3

f. Polypropylene Fibers Ratios : 0.7 and 1.5 kg/m^3

Specimens and testing:

a. Cube Size**:** 150 x 150 x 150 mm for compressive strength test

b. Beams Size: 150 x 225 x 1975 mm for flexural (two point) load test

c. Tests on concrete**:** Slump test, Two point load test, Compressive strength test.

d. Curing period: 28 Days

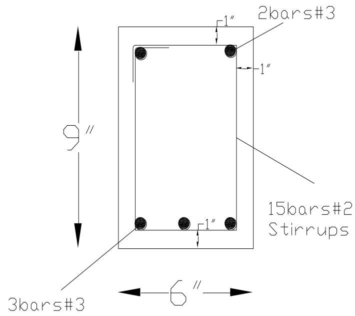

Figure 1. Cross section of a beam

Figure 2. Framework for beams

Figure 3. Mixing Fiber Cocktails

Table 1. Test Sample Details

DESCRIPTION	No of Samples in Groups of each ratio (No)	Total (No)
Group : A (Plain Concrete)		
Cubes (Controlled Samples)	3	3
Beams (Controlled Samples)	2	2
Group : B (Steel Fibers @ 60 kg/m³)		
Cubes (150 x 150 x 150 mm)	3	3
Beams (150x225x1975 mm)	2	2
Group : C (PP Fibers @ 0.7 Kg/m³) **D (PP Fibers @ 1.5 Kg/m³)**		
Cubes (150 x 150 x 150 mm)	3	6
Beams (150x225x1975 mm)	2	4
Group: E Cocktail Fibers @ (60 kg/m³ of Steel fibers + 0.7 kg/m³ of PP fibers) **Group: F Cocktail Fibers @ (60 kg/m³ of Steel fibers + 1.5 kg/m³ of PP fibers)**		
Cubes (150 x 150 x 150 mm)	3	6
Beams (150x225x1975 mm)	2	4
Total samples of beams **Total samples of cubes**		12 18
Total samples		30

Figure 4. Compression Test

2.2. *Testing Program*

The compressive strength test was carried out on 150 mm cubes cast from each group at the age of 28 days in a 3000 KN compression machine, as per BS 1881:Part 108,111,116:1983 Beams were tested for flexural strength also in a staining frame. One dial gauge was installed at mid span to record the mid span deflection and two gauges were installed at quarter points to record deflection at those points. Two point loads were applied at the centre of beams and deflections recorded for each increment of load.

Figure 5. Reaction Frame Apparatus

3. Results and Discussions

3.1. Compressive Strength

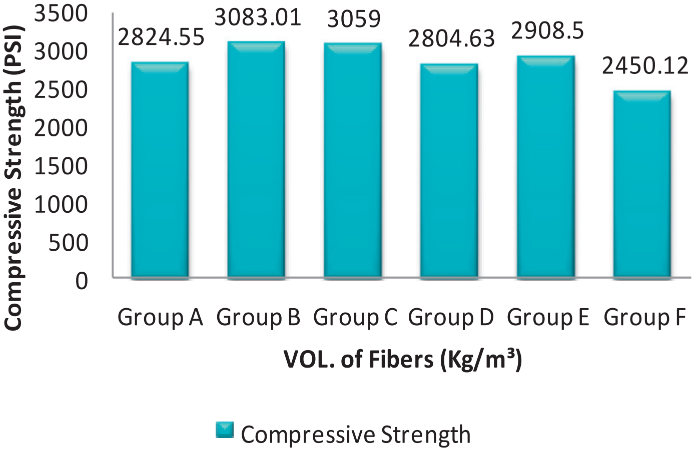

Figure 6. Compressive Strength Results

Figure 6 represents the graphical comparison of 28-days compressive strenth test results performed on test cubes cast in all groups. The results indicate that, on comparing the compressive strength of all the groups with controlled group A, compressive strength increases up to 9.5% for group B followed by group C in which compressive strength increases up to 8.5%. group F show a decrease in compressive strength which is up to 13%. It can be clearly observed from the results that, on increasing the volume of polypropylene fibers, the compressive strength decreases.

3.2. Flexural strength

Figure 7 shows the comparison of load versus deflection results for all groups while Figures 8 & 9 represent the deflection versus initial and final cracking and load versus initial and final cracking results respectively.

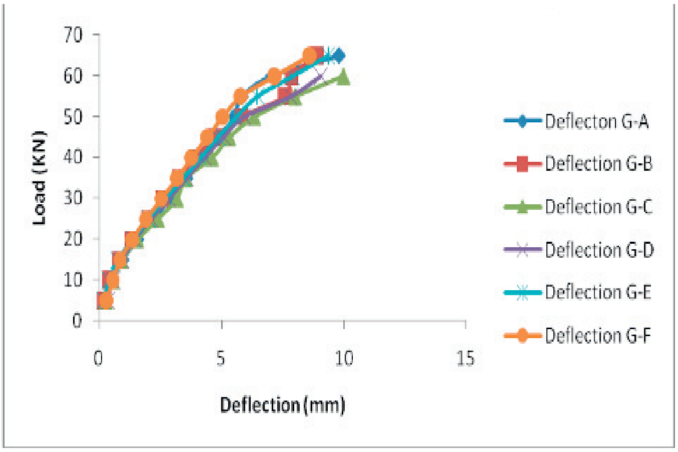

Figure 7. Load versus Deflection (comparison of all groups)

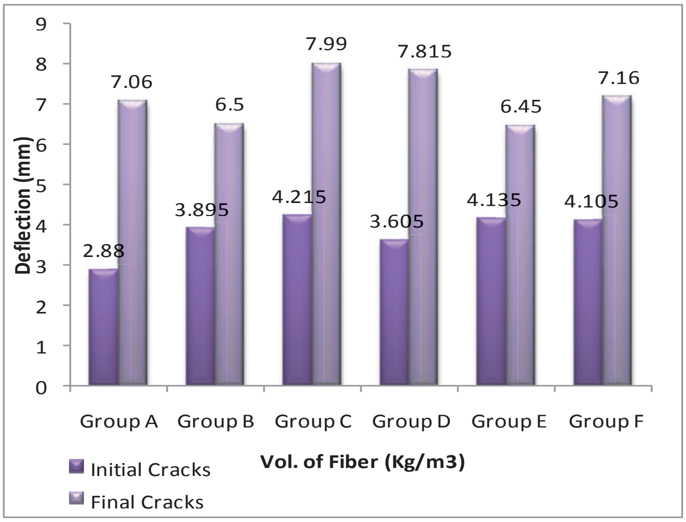

Figure 8. Reaction Frame Apparatus

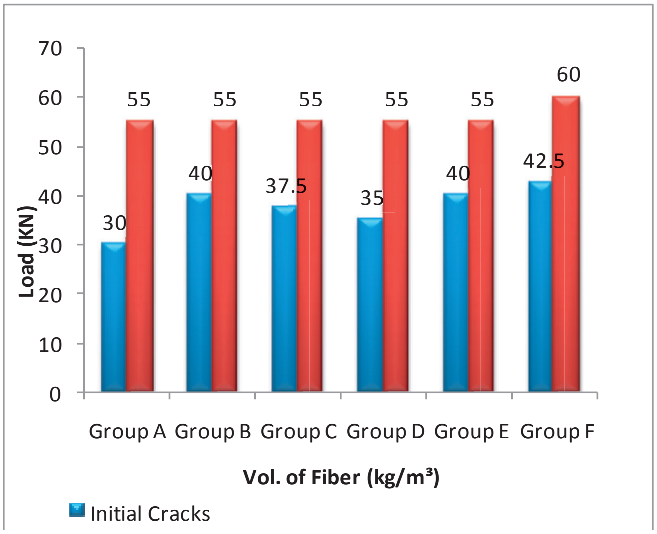

Figure 9. Reaction Frame Apparatus

The results indicate that, group F gives the highest increase in flexural strength for the initial cracks, which is 42% and also gives the highest increase in flexural strength for final cracks, which is 6.5% as compared to group A (controlled sample). Group B & group E also enhanced the flexural strength for initial cracks up to a remarkable increase, which is 34% as compared to group A (controlled sample).

4. Conclusions

1. Polypropylene fibers improve the plastic shrinkage cracking of concrete.
2. Initial cracking flexural strength increases with the addition of polypropylene fibers @ 0.7 kg/m³ (group C) but the strength remains constant till 1.5 kg/m³ (group D). After that strength may decrease. Cocktail fibers @ 60 kg/m³ of steel fibers + 1.5 kg/m³ of PP fibers (group F) gives the highest initial cracking flexural strength.
3. Fiber cocktail reinforced concrete gives the highest final cracking flexural strength that shows an improvement in post cracking behavior of concrete.
4. Maximum compressive strength is achieved in group B. Compressive strength decreases with increase in polypropylene fibers as in group C & D. Least compressive strength is obtained in group F, even less than group A.

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